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Solar cooking development in Algerian Sahara: Towards a socially suitable solar cooker

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ABSTRACT

This paper presents a review of research works and studies carried out in the development of solar cooking in Algerian Sahara. The review is performed in such way to focus on diverse box type solar cookers that have been realized by the solar heating research team at the Research Unit in Renewable Energies in Sahara Medium (URER/MS-Adrar, Algerian Sahara). Research started with the realization of a simple solar box cooker with a tilted absorber-plate, then the construction of a double exposure solar cooker and then the development of a novel non-tracking solar box cooker, which is equipped with a fixed asymmetric compound parabolic concentrator (CPC) as booster-reflector and its absorber-plate, is in a form of a step. The last cooker can be fixed at a south building wall with its rear opening in kitchen; it can be more user friendly. This will allow a freedom of interactive cooking and it does not require the user to go out in the sun during its use. These qualities promote its uptake and made it a socially acceptable device.

Contents

1. Introduction . . . 207
2. Principle of solar cooking . . . 208
3. Solar cookers classification . . . 208
4. Solar cooking in Algerian Sahara: A review . . . 209
   4.1. Development of a box type solar cooker with a tilted absorber plate . . . 209
   4.2. Development of a double exposure box type solar cooker . . . 209
   4.3. Contribution to the improvement of heat transfer into the pot in solar cookers . . . 209
   4.4. Development of a stationary building-integrated box type solar cooker . . . 210
5. Conclusion . . . 212
References . . . 213

1. Introduction

In Algeria, almost the whole country is supplied with electricity, natural gas and butane gas. These are all used for supply domestic needs. However, the problem of energy cost and the increasing energy consummation constitute an important ecological and economic constraint on the environment preservation and the sustainable development. Solar energy is a suitable solution to limit deforestation caused by the exploitation of firewood to provide domestic energy needs and to minimize the abusive use of energy derived from the fossil sources. Algerian Sahara lies in the sunny belt of the world. This area receives abundant daily sunshine and an average solar insolation of about 2650 kWh/m²/year [1].

Under these conditions, all solar energy applications could be developed and the solar cooking constitutes an attractive one. Cooking is an important part of daily food preparation in commercial and residential settings. The application of heat alters the composition of food products to enhance taste, texture, digestibility and shelf-life [2]. In the isolated Saharan areas; the use of heat for food cooking is very expensive when the conventional energy sources are used and induces

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disastrous consequences on the ecosystem by exploiting wood of the remaining trees in these areas.

In order to develop and popularize the use of solar cookers in Algerian Sahara, a research project was launched in 2004 by the Research Unit in Renewable Energies in Saharan Medium at Adrar, which is located at 27°53′N latitude and 0°17′W longitude. The Adrar area has a surface of 424,948 km²; it enjoys an average of about 3500 sunshine hours per year [1] and an annual average daily total solar irradiation on a horizontal surface of about 22.8 MJ/m² [3]. In addition, the sky is usually clear and it rarely rains. Under these conditions; solar cooking has a high potential of diffusion and constitutes a real opportunity in the domestic sector in this area.

This paper is a compilation of the research studies which were carried out to develop a socially acceptable solar cooker for the remote areas of Algerian Sahara and in particular Adrar region.

2. Principle of solar cooking

Solar cooking consists to use solar energy to cook food and prepare it for human consumption. To carry out this; it is necessary to:

- Collect the solar radiation;
- Convert it to heat;
- Retain the heat and transmit it to food through cooking pot walls.

This can be carried out by using a hot box type which depends on the green house effect. It consists of a well-insulated box with a black interior. Food is placed in cooking pots deposited on an absorber plate installed in the hot-box. The cover of the box usually comprises two glasses that lets solar radiation enter the box but keeps the re-radiation heat in the infrared region escaping. When a cooking pot is deposited on the absorber plate of a box-type solar cooker well-directed towards the sun; the heat transfer towards the food inside the cooking pot is carried out under the following conditions (Fig. 1)

- The absorber plate is irradiated on its upper surface; by natural convection, it transmits most of the absorbed radiation which is converted into heat towards the internal air. By conduction; it transmits a fraction of its heat towards the base of the cooking pot which is in direct contact with the absorber plate. Through the thermal wall resistance of the cooking pot; this fraction of heat is transferred to the food kept inside.
- The lid of the cooking pot absorbs a maximum of solar radiation but this surface remains not effective in the mechanism of heat flow to the food. Indeed; food is not in direct contact with the lid and it always remains an air gap between the upper surface of the food and the lid. The lid which becomes hot will generate, by natural convection, a current of hot air which circulates inside the box.
- The side surface of the cooking pot is partially irradiated and the heat carried by the air circulation inside the box, reaches the food via the side walls of the pot.

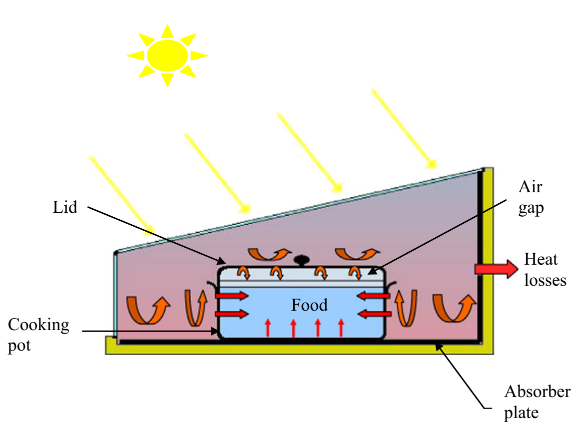

Fig. 1. A schematic diagram illustrating heat exchanges in a solar box cooker.

3. Solar cookers classification

In this study, available solar cookers are classified under two groups:

- Direct ones with integrated solar reflector–collector;
- Indirect ones with separate solar reflector–collector (split).

In the first group, we find the cookers whose collector and the place where the cooking pot is deposited, form one same unit. There are two types: The box type solar cookers which can be simple or provided with plane reflectors, and the concentrating ones. In box type solar cookers, the cooking pot is deposited in a well-insulated box and in the concentrating ones; the cooking pot is placed at the focus of a concentrating mirror.

In the second group, we find the cookers which are made in two distinct parts: A solar collector to collect and convert solar radiation into heat and an insulated cooking chamber for the installation of the cooking pot. These two parts are connected by ducts to allow the circulation of the heat transfer fluid and bring the heat to the cooking chamber. According to their collectors, we distinguish two types: Those with flat-plate collectors and those with concentrators.

Compared to those of the first group, the indirect solar cookers have the advantage of laying out the cooking chamber inside the kitchen. These cookers are complex and expensive; for more effectiveness their collectors are equipped with heat pipes. They must be the subject of a meticulous study when designing the home.

The parabolic solar cooker concentrates the direct solar radiation on the cooking pot which is installed in the focus of the parabolic concentrator. This type of cooker does not require a cooking chamber for the installation of the cooking pot. Indeed, the cooking chamber generates more obstruction which gene the reception of solar radiation, but the thermal losses become important under a strong wind. The use of this cooker requires a great attention for the concentrator orientation and to avoid the burns dangers. Since this type of cooker exploits the direct radiation, its operation under partially covered sky becomes practically impossible.

The box type solar cooker is simplest; it is about a hot-box directly exposed to the direct and the diffuse solar radiation. In order to improve the collected radiation, plane reflectors can be fixed on the box and oriented to reflect solar radiation towards the absorber plate. Box type solar cookers can be fabricated with locally available materials and they are easy to operate; they require only few interventions of the user for their orientations towards the sun, but reached temperatures are moderate and cooking times remain long.

Several models of solar cookers were built and distributed in the rural world through planet. In Africa and in the sub-Saharan area; popularization of solar cooking is supported by several organizations to fight against deforestation and meet populations needs in remote areas deprived of conventional energy resources like Tchad, Mali, Niger, Burkina-Faso and others…

With the actual ecological and economic current constraints, it is more than ever necessary to develop solar cooking in Algeria and particularly in its south regions.

4. Solar cooking in Algerian Sahara: A review

4.1. Development of a box type solar cooker with a tilted absorber plate

A first box type solar cooker prototype was constructed and tested in the Research Unit in Renewable Energies in Saharan Medium (URER/MS) in Adrar in 2004. This first prototype was constructed for a purely experimental aim [4]. It is built with locally available materials: plywood, glass mirrors and a black steel sheet as an absorber plate. The door, fixed on the top, consists of a movable double-glass cover. Three glass mirrors are hinged to the framework of the upper edges of the box. The photograph of the box type solar cooker prototype is shown in Fig. 2; it is fixed over an angle iron stand facing south. The reflectors tilt angles and the cooker azimuth are adjusted at regular intervals of 20 min to ensure that the reflected and the direct solar radiations fall on the cooker aperture.

Experimental tests were carried out under the actual climatic conditions of Adrar in absence of wind and under clear sky condition. The effectiveness of cooker was demonstrated by the cooking tests of different food items: chicken, meat, rice, coffee and tea. Various stagnation tests were carried out in January 2005 for winter season and in June 2005 for summer season. At winter season and under stagnation test conditions; the maximum absorber plate temperature achieved at 14:50 was 148 °C.

Water heating tests were conducted according to the International Standard procedure for testing solar cookers developed by Funk [5]. Under hot season climatic conditions, it took about 2 h to boil 1.25 kg of water.

4.2. Development of a double exposure box type solar cooker

On the basis of the obtained results in the precedent study; our work was directed towards the development of a box type solar cooker equipped with a linear parabolic concentrator allowing a double exposure of the absorber plate [6,7]. It consists of a box type solar cooker with a double glazed bottom which allows the absorber plate to receive solar radiation on its lower side with the help of a parabolic reflector disposed under the cooker. The cooker box is equipped with three glass mirrors hinged to the framework of upper side of the cooker. In this manner, the absorber plate is exposed to solar radiation from two sides. A door is provided on a lateral side of the box to access the cooking vessel. The parabolic reflector is a section of a linear parabolic concentrator.

Fig. 2. Photograph of the box type solar cooker prototype realized at the URER/MS.

Fig. 3. Photograph of the double exposure solar cooker prototype realized at the URER/MS.

The photograph of the double exposure solar cooker prototype is shown in Fig. 3.

An experimental study was carried out under the actual climatic conditions of Adrar from September 2005 to September 2006. During tests, the cooker was manually oriented according to azimuth at an interval of 15 min in order to collect a maximum of solar radiation. Under stagnation test conditions; the maximum absorber plate temperature achieved at 10:00 h was 173 °C, measured at a horizontal solar radiation value of 677.3 W/m² and an ambient temperature equal to 38 °C. Several water heating tests were carried out in winter and in summer with different water loads. Under winter season climatic conditions, it took about 78 min to boil 1 kg of water.

Compared with the first box type solar cooker prototype, the reached temperatures are higher and boiling time of 1 kg of water is reduced.

4.3. Contribution to the improvement of heat transfer into the pot in solar cookers

The heat transfer into the pot in solar cookers of different types was the subject of a number of experimental and theoretical studies [8–15]. It was observed that typical cooking times are about 2 h to 3 h for box types and 1 h to 2 h for concentrating types. For a given type of solar cooker it is possible to reduce the cooking time by carrying out modifications on the shape of the cooking vessel. These modifications can improve heat transfer to the food through the pot walls. In this objective Harmim et al. [16] investigated a finned cooking vessel in order to increase efficiency of solar cookers and to reduce cooking time. The tested pot is an ordinary cylindrical cooking vessel whose lateral external surface is provided with fins distributed around the circumference. This configuration increases the surface of heat transfer towards the interior of the vessel and keeps an adequate volume to contain the food to be cooked.

A comparative experimental study of a box-type solar cooker with two different cooking vessels was conducted in Adrar, Algeria. The two cooking vessels are made of aluminium painted black, are cylindrical in shape and have flat base. The lateral external surface of one of the cooking vessels is provided with fins made of aluminium painted black. Fins are of rectangular constant cross section. The solar cooker used in the experimental investigation is of the double exposure type (Fig. 3). During each test, both cooking vessels were placed side by side on the absorber plate and loaded with the same quantity of water at the same temperature.

It was found that water temperature in the finned cooking vessel was always higher than water temperature in the conventional cooking vessel. It was experimentally demonstrated that cooking time can be reduced by using a finned cooking vessel. This reduction is consistent with the increase of the heat transfer surface area by fins attached to the external surface of the cooking vessel.

It is clear that increase in temperature of the internal air, in contact with side walls of the cooking vessel, can improve heat transfer into the pot in solar cookers and then improve performances of the cookers. The effect of box geometry, such as cylindrical and rectangular, on the performance of solar cookers has been investigated by Kurt et al. [17]. It was observed that cylindrical model has higher temperature than the rectangular one under the same operating conditions. Harmim et al. [18] have investigated the effect of a finned absorber plate on the box-type solar cooker performance. The finned absorber plate enhances the rate of heat transfer to the air inside the cooker. A comparative experimental study was carried out to compare the thermal performance of two box-type solar cookers prototypes under same operating conditions. Two identical prototypes of box-type solar cookers have been designed and fabricated; the first one equipped with an ordinary absorber plate and the second one equipped with a finned absorber plate. Each prototype consists of a wooden case from which sides and bottom were thermally insulated. The case is provided with an inclined movable double glass cover hinged to one side of the case at the top.

For the first prototype; the absorber plate consists of an aluminium sheet painted black. For the second one; the absorber plate is similar to that of the first one but its upper surface is provided with fins made of aluminium painted black. Fins are of rectangular constant cross section. The photograph of the two prototypes, used in the comparative study, placed side by side on the experimental platform is shown in Fig. 4. A series of experiments have been performed under Adrar prevailing weather conditions in July 2008 and the following conclusions have been drawn:

- Finned absorber plate improves the performances of the box-type solar cooker by reduction of the cooking time by 12% compared to an ordinary absorber plate; this was obtained by the improvement of the heat exchange between absorber plate and internal air.

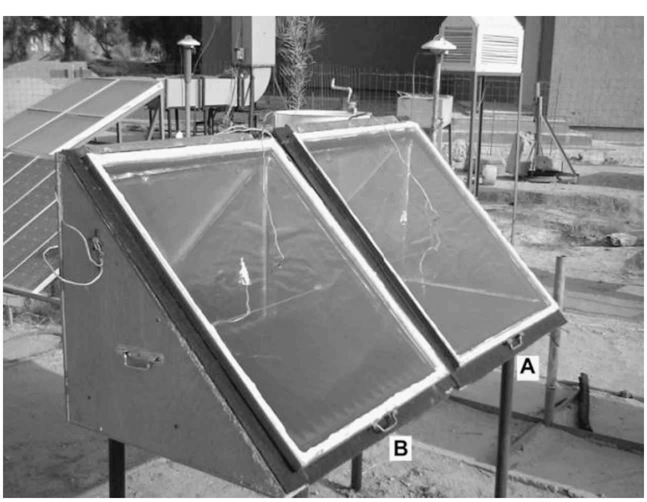

Fig. 4. Photograph of the two box type solar cookers used in the present comparative study, placed side by side on the experimental platform. “A” is equipped with ordinary absorber plate and “B” is equipped with finned absorber plate [18].

- The stagnation temperature for box-type solar cooker equipped with a finned absorber was about 7% more than box-type solar cooker equipped with an ordinary absorber.

The attached fins on the absorber plate increase its temperature by radiative absorptance due to different multiple reflections. The temperature improvement of the interior hot air is obtained by the increase in the convective heat transfer plate-air surface.

The finned absorber plate is recommended for use in box-type solar cookers.

4.4. Development of a stationary building-integrated box type solar cooker

An original application of the Mallick's asymmetric Compound Parabolic Concentrator (CPC) [19], which is used as booster-reflector for a box-type solar cooker, was presented by Harmim et al. [20]. A schematic diagram of the proposed system is presented in Fig. 5. A solar cooker equipped with an asymmetric CPC consists of an insulated box with a vertical double glazing cover on a side and two linear parabolic reflectors (upper and lower parabola) fixed on the glazed side of the box. The geometrical properties of the booster-reflector in form of an asymmetric CPC were calculated for a box-type solar cooker, to operate in Adrar, Algeria.

The mathematical model of heat transfer processes involved with this cooker, containing a cooking pot loaded with water, was developed and the effects of various parameters, such as solar radiation, clouds and water load on the dynamic behaviour of the cooker were studied [20]. The results demonstrate competitiveness and promising performance of this cooker; thus a prototype was constructed and tested. The experimental study was conducted in the winter and summer seasons. The cooker performance was rated by using the first figure of merit ($F_1 = 0.1681$ °C m²/W) and the second figure of merit

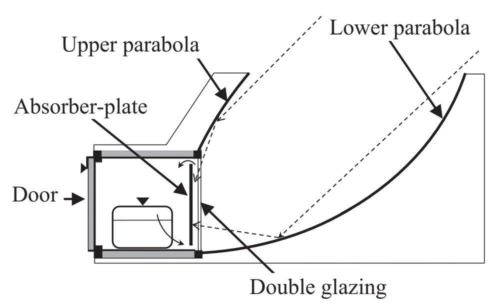

Fig. 5. Schematic sketch of the box-type solar cooker employing an asymmetric CPC as booster-reflector.

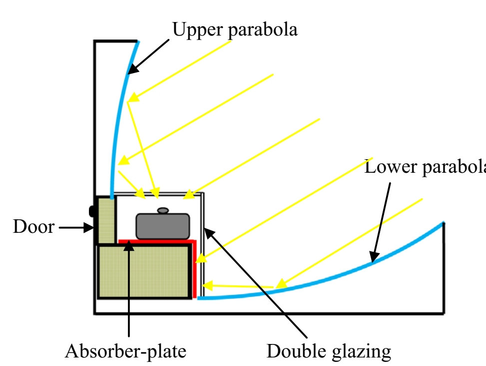

Fig. 6. Schematic sketch of the non-tracking box-type solar cooker employing a line-axis asymmetric CPC as booster-reflector and an absorber-plate in a form of a step.

(F_2=0.35) [21]. Experimental tests demonstrated that the cooker, which remains in a stationary position during all test period, is suitable for cooking even in winter and without having recourse to tracking towards the sun. But by comparison with those which are developed elsewhere; the efficacy of this cooker remain relatively average. Efforts have been made to make changes to the internal geometry of the cooker box and the shape of the absorber plate in order to improve the effectiveness of the cooker. A schematic diagram of the novel cooker prototype is presented in Fig. 6. It consists of a solar cooker that is equipped with a non-imaging line-axis asymmetric CPC and an insulated parallelepipedic box with a vertical transparent glass cover on a side and a horizontal transparent glass cover on the roof. The absorber plate is bent in right angle in a form of a step. It is laid out, so that its vertical surface is parallel to the glass cover on side by forming a space allowing the circulation of hot air upward the cooker box cavity, which is delimited by the roof glass and the horizontal surface of the absorber plate. The absorber plate has a negligible thermal capacitance (thin plate) and its exposed surface is painted black to increase solar radiation absorption. Two linear parabolic reflectors (upper and lower parabola) are fixed on the glazed walls of the box. The two reflectors are arranged so that, incoming solar radiation received by the aperture is reflected towards the absorber plate. According to the solar altitude angle; the focal spot that is formed by the upper parabola moves on the horizontal surface of the absorber plate and the focal spot that is formed by the lower parabola moves on the vertical surface of the absorber plate. A prototype of a box-type solar cooker with an asymmetric CPC of an acceptance angle of 60° was constructed by means and materials available in Adrar. The internal dimensions of the box receiving the cooking pots are 0.7 m per 0.28 m per 0.14 m height. Its top transparent cover consists of a double glazing of 4 mm thickness, 0.7 m length and 0.3 m width and its side vertical transparent glass cover consists of a double glazing of 4 mm thickness, 0.7 m length and 0.36 m height. So its total glazing area is 0.462 m². The absorber plate, painted by a non-selective matte black paint, is made of stainless steel sheet of 0.3 mm thickness and is bent so as to present a horizontal surface of 0.7 m length and 0.26 m width and a vertical surface of 0.7 m length and 0.2 m height. It is placed at 2 cm from the vertical glass cover and is insulated, on its rear side, with a glass wool layer of 15 cm thickness. On the opposite side of the vertical glass cover, a door is provided to access the cooking pot. The two other box internal side walls are made of stainless steel sheet of 0.3 mm thickness and insulated with a glass wool layer of 5 cm thickness. A photograph of the novel solar cooker prototype is presented in Fig. 7. Experimental tests of the solar cooker were conducted in Adrar, Algeria. The thermal performance of the solar cooker is evaluated by conducting two types of test, stagnation tests and sensible heat tests. The various tests carried out under the real climatic conditions of Adrar, demonstrate its effectiveness to cook two meals per day for a family of four persons.

Fig. 7. Stationary building-integrated solar cooker prototype [22].

During stagnation tests of the cooker equipped with its reflector, the maximum absorber plate temperature reached 166 °C and 165 °C in summer and winter season respectively. When the reflector was removed, the maximum absorber plate temperature reached 127.7 °C in winter season.

The cooker performance was rated by using the first figure of merit (F_1=0.152 °C m^2/W) and the second figure of merit (F_2=0.470). The values of first figure of merit F_1 and second figure of merit F_2 are compared with other box type solar cookers in Table 1.

The adjusted cooking power is calculated according to the International Standard procedure. For that; experimental tests have been conducted on five days from February 24th, 2013 to Mars 1st, 2013. Intercept area of our cooker equipped with its reflector has been found to be 0.712 m², so the water load for cooking power test has been taken 5 kg distributed evenly between three cooking pots. Using all obtained results on five days and according to International Standard procedure, we deduced the relation which gives the adjusted cooking power P_{ad} (W) as a function of the temperature difference ΔT (°C) of water load and ambient temperature

$$P_{ad} = 136.28 - 1.142\Delta T \quad (1)$$

The value of the linear regression coefficient of determination $R^2 = 0.936$ satisfies the test standard (better than 75%) and the standardized cooking power (cooking power at 50 °C) is found to be 78.9 W [22]. The adjusted cooking power is compared with other box- type solar cookers in Table 2.

The experimental energy and exergy efficiencies are also calculated. When water is heated from 40 °C to 90 °C, then for each 10 min time interval, the energy efficiency of the cooker will be calculated by [27]

$$\eta_{en} = \frac{M_e C_e (T_{e2} - T_{e1})}{I_{in} A_{in} \Delta t} \quad (2)$$

where I_{in} is global solar radiation on intercept area of the cooker,

Table 1
Comparison of F_1 and F_2 of our novel solar cooker with other box-type solar cookers.

Refs.	F_1 (°C m²/W)	F_2	Amount of water load (kg)
Kumar et al. [23]	0.117	0.467	2
Negi and Purohit [14]	0.1252	0.4051	–
Purohit and Purohit [24]	0.1251	0.4805	1.844
El-Sebaii and Ibrahim [25]	0.15	0.407	4
Mahavar et al. [26]	0.116	0.466	1.2
Our novel cooker [22]	0.1522	0.478	3.5

Table 2
Adjusted cooking power expression of our novel solar cooker compared with other box-type solar cookers.

Refs.	Adjusted cooking power	Standardized cooking power (W)
Funk [5]	$P_{ad} = 125 - 1.58\Delta T$	46
El-Sebaii and Ibrahim [25]	$P_{ad} = 103.92 - 1.598\Delta T$	24.02
Mahavar et al. [26]	$P_{ad} = 103.5 - 1.474\Delta T$	29.8
Our novel cooker [22]	$P_{ad} = 136.28 - 1.142\Delta T$	78.9

A_{in} is intercept area of the cooker, Δt is time interval and, T_{e1} and T_{e2} are, respectively, initial and final water temperature for the considered time interval. And its exergy efficiency will be calculated by [27]

$$\eta_{ex} = \frac{Ex_o}{Ex_i} = \frac{M_e C_e (T_{e2} - T_{e1}) - M_e C_e T_{amb} \ln \frac{T_{e2}}{T_{e1}}}{I_{in}\left[1 - \frac{4}{3}\left(\frac{T_{amb}}{T_s}\right) + \frac{1}{3}\left(\frac{T_{amb}}{T_s}\right)^4\right] A_{in} \Delta t} \tag{3}$$

where T_s is surface temperature of sun (6000 K) and T_{amb} is ambient temperature. For the test conducted on February 26th, 2013; the variation of the instantaneous energy and exergy efficiencies as function of time for the cooker is presented in Fig. 8.

As for any solar system, the energy efficiency of our solar cooker prototype, decrease linearly with time (from 27% to 5%) as the temperature rises and the thermal losses increase. The exergy efficiency of the cooker is weaker (0.5–2.5%); it varies in step with solar radiation and presents a peak during the test.

As proposed by Kumar [27], the quality factor, the peak exergy power gained and the heat loss coefficient also evaluated. The peak exergy power gained is the maximum exergy power output obtained through curve fitting by plotting the graph between exergy power output ($Ex_o/\Delta t$) and temperature differences of water load and ambient temperature (Fig. 9). The exergy power lost (the second term on the numerator of exergy efficiency

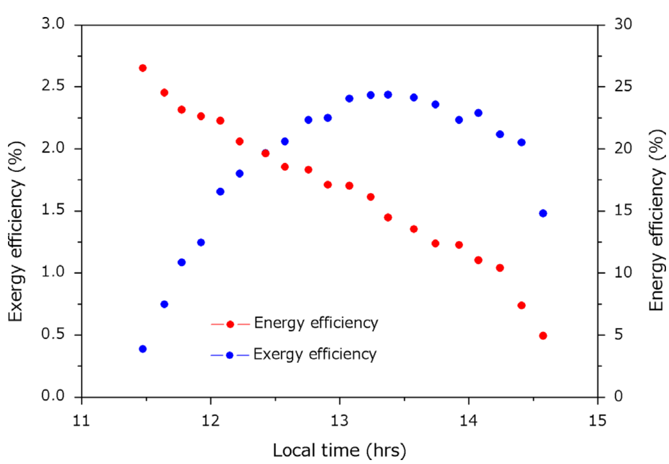

Fig. 8. Variation of energy and exergy efficiencies of the novel solar cooker versus local time on February 26th, 2013.

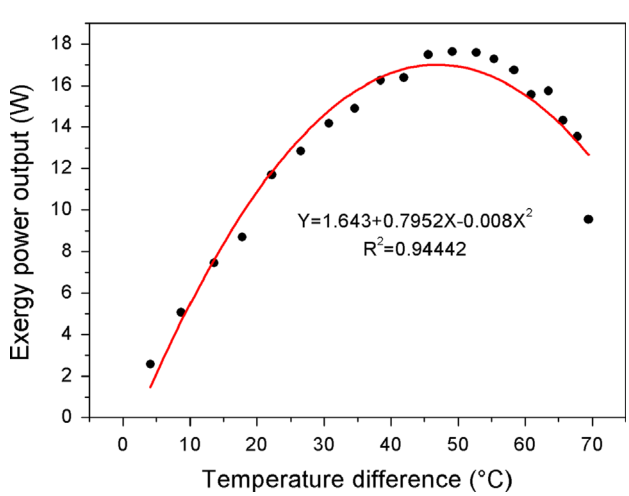

Fig. 9. Variations in exergy power output with temperature difference for the novel solar cooker on February 26th, 2013.

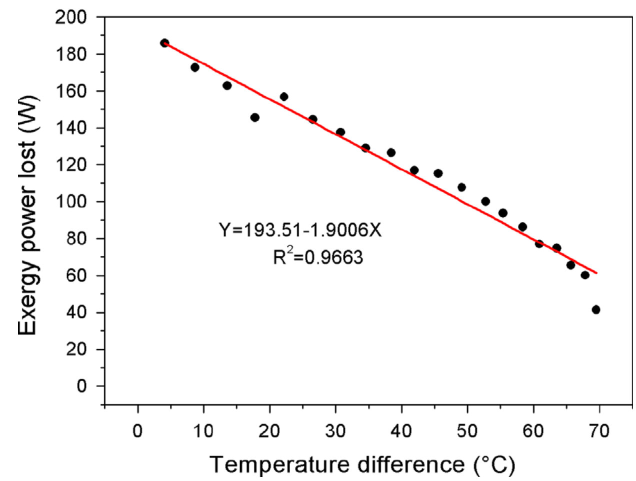

Fig. 10. Variations in exergy power lost with temperature difference for the novel solar cooker on February 26th, 2013.

expression) is also plotted versus temperature differences in Fig. 10. The quality factor is defined as the ratio of the peak exergy power gained to the exergy power lost at the same instant of time. From Fig. 9, the peak exergy power gained is determinate to be 21.4 W at 49.70 °C and from Fig. 10, the exergy power lost at the same temperature difference is determinate to be 99.05 W. The quality factor is then equal to 0.216. The heat loss coefficient is obtained by dividing the value of the slope of the line, obtained through linear curve fitting of the exergy power lost variations with temperature difference, by the value of glazing area (0.462 m²). It is then determined to be 4.09 W/m² K. These performance indicators are compared with those of other solar cookers in Table 3. Our novel solar cooker prototype is characterized by a higher quality factor.

Several cooking tests of various food items were carried out with our prototype in winter season. They were carried out with a rhythm of two meals per day and for four persons. Meals were diversified: Bread and sheep or chicken stew, green and dry vegetables, macaroni and rice [22]. This system remains in a yearly stationary position during all cooking period; it can be integrated into the kitchen wall of a building (Fig. 11) and could be then exploited without having to go out at the sunshine.

In designing the novel solar cooker, the objective is to maintain the cost minimal. The overall cost fabrication was estimated at $104.5. Costs estimation of the various components is given in Table 4. It should be noted that prices of various construction materials are given according to the Algerian market and costs were estimated for fabrication of a prototype for research purpose. The overall cost of fabrication would significantly decrease if the solar cooker will be fabricated for commercial purpose.

5. Conclusion

This paper presents a detailed literature survey of research works carried out in the development of solar cooking in Algerian Sahara. This activity lies within the scope of the program of the Research Unit in Renewable Energies in Saharan Medium (URER/MS—Adrar, Algeria) for the development of solar systems. The activity which started in 2004 has leads to the development of an innovative building-integrated box type solar cooker. Apart the thermal storage to ensure cooking in the evening, our new cooker guaranteed majority of the requirements for a domestic exploitation. It is simple, low cost, user friendly and efficient even in

Table 3
Comparison of performance indicators of our novel solar cooker with other solar cookers.

Solar cooker type	Indicator				
	Peak exergy Power (W)	Heat loss coefficient (W/m² K)	Quality factor	Maximum exergy efficiency (%)	Maximum energy efficiency (%)
Truncated pyramid type solar box cooker [27] m=2 kg	7.12	4.09	0.15	3.89	36.38
Domestic solar box cooker [28] m=2.5 kg	6.46	5.24	0.123	–	–
SK-14 (domestic) [28] m=5 kg	18.21	40.35	0.106	–	–
Parabolic trough [28] m=6.3 kg	6.92	54.12	0.087	–	–
Scheffler (community) [28] m=20 kg	55.75	47.73	0.099	–	–
Our novel solar cooker m=5 kg	21.40	4.12	0.216	2.43	27.15

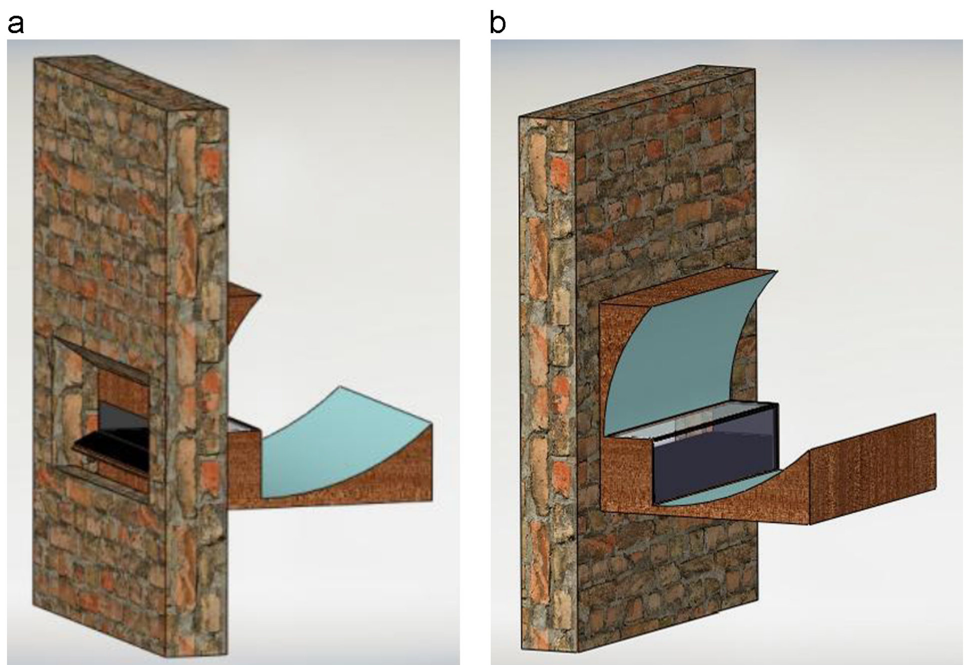

Fig. 11. Schematic sketch of our novel solar cooker integrated into building wall [22]. (a) Internal and (b) External sides.

Table 4
Cost estimation of the various components of our novel solar cooker prototype.

Component	Cost (US$)
Steel sheet for the absorber plate (0.3 mm thickness)	4.5
Glass wool for the thermal insulation	5
Plywood for the external box walls (8 mm thickness)	16
Glazing for the transparent cover (4 mm thickness)	11.5
Glass mirrors for the reflector (4 mm thickness)	22
Various (screws, nuts, hinge, sealant, painting)	9
Total materials	**68**
Labour cost (2 workers, 2 day)	36.5
Overall cost fabrication	**104.5**

winter. These qualities promote its uptake and made it a socially acceptable device.

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